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Small-Wind and Residential Photovoltaic in Nebraska: Barriers to Development

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SMALL-WIND AND RESIDENTIAL PHOTOVOLTAIC IN NEBRASKA:

BARRIERS TO DEPLOYMENT

by Jerrod Bley

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Abstract

Currently in the U.S. Energy sector, business-as-usual involves emitting billions of metric tons of harmful Green House Gas (GHG) into the environment each year, for electricity generation alone (Energy Information Administration [EIA] 2012). The Earth's capacity to capture and store the harmful GHGs that threaten human and ecological health is being tested. In 2008, Nebraska's anthropogenic CO_2 emissions by the Residential sector were 2.8 million metric tons, and roughly 39% of the emissions came from electricity consumption. In the same year the total amount of CO_2 emissions from coal-fired power plants was 27.1 million metric tons (EIA & Nebraska Energy Office [NEO] 2012). The need to reduce "dirty" electricity and promote sustainable, clean electrons is evident. Many obstacles have curtailed adoption of Renewable Energy (RE) since it was recognized as a possible solution to environmental degradation. This report explores the economic, social, and technological barriers to RE adoption in Nebraska. The findings suggest that barriers are intertwined with one another. Each obstacle is connected to the others, and lends explanation to the limited receptive environment in the state. Causes and possible solutions to barriers are also investigated. There is no "silver-bullet" to the clean energy debate. It is a complex issue with an array of solutions and possible answers. Recognizing the problem is in many ways, the first step to fixing it.

Introduction

The issue of renewable, clean-energy for America has swept the media and the halls of government at every level. Citizens of the United States and across the world have been exposed to concepts of alternative energy systems, and yet we have not acted. I find it important to ask the question: “What are the factors preventing people from adopting the technology and making it part of their lives”? In this study I have researched three primary elements that have created barriers to the adoption of residential-scaled RE systems in the state of Nebraska.

Of all the obstacles, the financial barrier associated with residential RE systems is the most insurmountable. Consideration is given to the up-front cost of installing a RE system, as well as the annual Operating and Maintenance (O&M) costs associated with each technology used in the data collection portion of the research. Included in this study is a cost-benefit analysis (CBA) of a residential scale RE system in both a rural and urban environment. Also investigated are the social-organizational elements that have prevented society from fully embracing RE system in their homes. Cultural dynamics, such as a deep-rooted history in Public Power, current energy policy, and people’s willingness to invest in RE will impact the degree of adoption. The final topic of research focuses on the technological aspect of implementing RE systems in the two different application environments. I have examined the technologies used in each system to compare efficiency and actual output of each system compared to nameplate capacity.

The two RE systems are Photovoltaic (PV) and a small-wind turbine system. The PV application was in an urban setting in Lincoln Nebraska. Photovoltaic systems are commonly referred to as solar panels or solar arrays. PV cells harness the energy in sunlight and transform that energy into electricity (*Sunshot Vision Study* 2012). The small-wind system was in a rural setting in Norfolk, Nebraska. Wind turbines convert the energy in airflow to mechanical and finally electrical energy using a generator (*Small Wind Energy Guide* Department of Energy [DOE] 2007).

Qualitative data was obtained through the analysis of a survey conducted of Nebraska's wind industry stakeholders by UNL's Electrical Engineering Department and Biological Systems Engineering Department and in collaboration with National Renewable Energy Laboratory (NREL). Assumptions associated with this portion of the study are unrealistic representations by those who answered the questionnaire as a result of attention bias. The data collected is not anonymous random sampling, and cannot be considered statistically significant, but none-the-less provides helpful insight into the attitudes and behavioral aspects of the key stakeholders located in Nebraska.

During my research I valued a hands-on approach to the study that provided me with experiential learning related to the topic of this paper. In Nebraska small-wind and PV systems are more abundant compared to other residential-scale RE systems, such as micro-hydro, and provided the greatest opportunity to gather secondary qualitative data for my thesis, because the natural resources to support these systems are present (American Wind Energy Association [AWEA] 2011; NEO 2006). I have worked with the Department of Biological Systems Engineering and the Department of Electrical Engineering on small wind turbine and solar array installation project located at the University of Nebraska -Lincoln's (UNL) Haskell Ag Laboratory located near Concord, NE. I was also fortunate enough to assist in the installation of a tracking solar array and two Skystream 3.7 small-wind turbines near Lyons, NE with the Nebraska Renewable Energy Association (NeREA). The vital hands-on approach I have utilized has provided me with a more functional understanding of RE system components installation and application of RE systems.

Many people in Nebraska consume large amounts of electricity without ever thinking about where it comes from, or the ecological impact of using so much energy in an unsustainable manner. The already high demand for electricity in the United States is projected to grow over the next twenty-five years (EIA 2011). Social trends perpetuating increases in energy use have emerged as people become ever more *plugged-in* to electricity consuming products such as, laptops, tablets, music players, and mobile phones. As a result people will demand more electricity to supply the energy needed to achieve the quality of life they will pursue and want. Energy, in the form of electricity, allows humans to organize thoughts, creativity, and innovation. Electricity allows people to communicate and interact. These interactions are the foundation of our market economy and the basis for building wealth. I have analyzed the market signals and market failures that influence consumer's choice to invest in RE systems. It is of key importance to identify the behavioral aspects that compel consumers to make decisions regarding energy consumption (Gallagher, Holdren, Sagar, 2006). Factors have been identified and analyzed that persuade choice. Findings are analyzed and applied toward developing ways to alter or adjust the influences that prevent residents from implementing RE systems in their homes. I have attempted to surmise why the people of Nebraska have not been more receptive to the possibilities provided by RE systems.

Currently within our commodity market, fossil fuels are a finite resource that will eventually be exploited to a point where it is no longer cost effective to extract them, and presently with no way for humans to reproduce such resources on the immense scale needed by the world's population. Today, the United States produces roughly 45% of its electricity with coal-fired generation facilities. These power plants are a major point source of airborne pollutants and GHGs such as Carbon Dioxide (CO_2), Sulfur Dioxide (SO_2), Particulate Matter (PM), Nitrogen Dioxide (NO_2), and Mercury (Hg), which are hazardous to both human health and the ecosystem. Coal fired powered plants also produce high amounts of Nitrous Oxide (N_2O), which is a GHG 310 times more powerful at trapping heat in the atmosphere than CO_2, and contributes to Global Climate Change (EPA 2012). In Nebraska the 2010 CO_2, SO_2, and NO_2 emissions numbered 24 million, 64 thousand, and 40 thousand metric tons, respectively (EIA 2012). Reduction of electricity generated via fossil fuels, namely coal, will have a significant impact on the preservation of critical ecosystems relevant to Nebraska and the individual natural systems that compose such bionetworks (Backlund, Janetos, & Schimel 2008, EIA 2012, IPCC 2007). The degree to which emissions are reduced and environmental degradation is mitigated depends on the extent to which residents adopt RE and begin using clean electricity.

The scope of this study is limited to electricity generation on a residential home-scaled RE system. Only investigating small wind and PV technologies inherently lends itself to limitations when exploring the possibilities of all Renewable Energies. Another limitation is the three elements (economic, social, and technological) I chose to explore. There are other barriers that contribute to the question at hand. Taken singularly, the three identified factors alone do not explain the whole picture. However, the many sub-categories I have lumped into each element attempts to make connections to one another, and to support the argument for RE in Nebraska. Another categorical barrier that is touched on, but not investigated in depth is the lack of *awareness and education* regarding the potential of RE in the Residential sector. The Intergovernmental Panel on Climate Change (IPCC) has identified these two elements as a major barrier to RE adoption, a statement to which I agree, however my interest in the issue falls within the three barriers examined within this paper (IPCC Special Report on Renewable Energy and Climate Change Mitigation [SRREN] 2011).

Much work has been conducted on the issues I have highlighted above, and documented in scientific journals, articles, reports, and books. I have read and reviewed these resources in an attempt to learn and broaden my understanding of the importance surrounding my thesis topic. In the next section I will discuss several key findings that have provided insight related to my study.

Literature Review

Identifying Sustainability

Integrating existing RE systems into the Residential sector can provide relief to utility companies in Nebraska searching for ways to mitigate the construction of new generation facilities, transmission lines, and supporting technologies. Nebraska is unique in that it is the only state in the nation to have 100% publicly owned power. Meaning entities such as the Nebraska Public Power District (NPPD) and the Omaha Public Power District (OPPD) are publically owned corporations and political subdivisions of the state (NPPD & OPPD 2012). RE systems in the home can help reduce peak load supply issues experienced by public utilities and retail electric utilities that provide electricity to end-users in the residential, commercial, and industrial sectors. Lincoln Electric Systems (LES), for example, provides service to around 275,000 people over a 200 square mile region within Lancaster County. The Residential sector is the largest sector LES provides service to, accounting for 87.43% of LES customers as of December 31, 2010. Also in 2012, LES reported that the Residential sector used, on average, 10,866 kWh per customer (LES 2012). The expectation of a growing customer base and an influx of citizens into the state will require greater generation capabilities in the future as people demand more electricity to maintain the quality of life they have come to expect. With greater adoption of RE systems, public utilities and retailers can keep rates competitive and provide the same level of quality service, without constructing new facilities and miles of transmission lines throughout the state.

The topic of *sustainability* is broad and may have different meaning depending on the context in which it is referred to. It is important to define *sustainability* in relation to RE systems. I have attempted to draw the connection between generating electricity in the home with existing and forthcoming technologies, and doing so in a manner that is least harmful to the environment and the ecosystem. Renewable Energy technology refers to the ability to produce electrons, for use by people, to power appliances and lights, operate HVAC systems, charge batteries, run center-pivot irrigation pumps, and any other application that electricity is currently employed to do for the people of Nebraska. The key is to apply this technology in a manner that is long-term, requires little to no fuel source, and greatly reduces GHG emissions compared to fossil fuel burning technologies. Sustainable systems work alongside natural systems causing minimal disturbance where interference does occur. Sustainable systems use the natural resources provided in the area to provide the fuel source efficiently and abundantly; not at the expense of crucial habitat needed by plants and animals, and not by exploiting mineral and fossil fuel reserves within the earth. Sustainable systems exist in unison with nature, not at odds with it. In the paper titled *Analyzing Sustainability of Community-based Energy Technologies* the authors Khan, Chhetri, and Islam (2007) state:

> Most modern technologies are developed on principles that focus on short-term economic benefits. However, “good” technologies can be developed following the principles of nature. In nature, all functions or techniques are inherently sustainable, efficient, and functional for an unlimited time period. In other words, as far as natural processes are concerned, time tends to Infinity. (p. 406)

Sustainable RE systems may be possible based on Khan, Chhetri, & Islam’s criteria of available time for the useful life of the product, and a significant reduction in GHG and non-

GHG emissions from the technology being used. It is however, unrealistic to expect the future RE technologies that will be deployed to be manufactured and transported without some degree of embodied energy coming from fossil fuels. The mining of ore materials (e.g. iron, aluminum, cadmium) and subsequent hazardous substances (e.g. silicon tetrachloride [$SiCl_4$]) used in the manufacture of PV cells is harmful to the environment (Mulvaney et al & Silicon Valley Toxics Coalition [SVTC], 2009). I recognize both sides of the argument for sustainability relative to RE technologies. The reality that the “perfect” sustainable technology exists is unlikely. In order to produce the PV cells and small wind-turbines requires that humans exploit the earth and extract the necessary raw materials; but the key to adoption of these technologies and the deployment is that the fuel sources are virtually infinite, free, to a certain extent predictable, and emissions free. Unlike conventional generation facilities that burn fossil fuels for their construction, maintenance, and daily operations, RE systems likely seem the better choice for a sustainability future.

The remainder of this section will review several key articles, reports, and case studies that focus on the three major realms of my study: economics, social aspects, and technology. I have investigated what previous research has concluded on these areas of interest and how they apply to RE systems and the end-user in Nebraska.

Solar PV

Review of pertinent literature was essential in identifying present barriers associated with RE adoption in Nebraska. This section highlights and discusses in further detail past work conducted in this field in relation to PV adoption in particular.

The Technology Issue

First, it is important to understand the basic structure of PV modules in order to realize the effects manufacturing of PV semiconductor materials have on the economic and environmental landscape. Modern Photovoltaic modules were first designed in the 1950's and have increased in efficiency since and decreased in cost. PV is considered a mature technology, with large leaps in efficiency not considered likely in the near-term. This means residents considering PV installation should not be influenced by the possibility of emerging technologies making older systems obsolete. PV technology is fairly robust, with useful life span of 20 years and greater (IPCC SRREN 2011). Many modules and systems installed in the 1980's are still producing electricity today. Cost and efficiency ratings for the wide array of commercially available PV modules are a function of the semiconductor material. According to the Solar Energy Industries Association (SEIA) the most common types of PV cells are Crystalline Silicon (c-Si), Polycrystalline and Single-Crystalline Thin-Films (thin-films), with c-Si being the most prolific in the industry. Refer to **Figure 4** in the appendix for a graphical illustration of the efficiency ratings for the different types of semiconductor materials.

The U.S. Department of Energy's (DOE) Energy Efficiency and Renewable Energy (EERE) department's 2010 Solar Technologies Market Report provided an invaluable amount of information regarding PV technology's relationship with the U.S. Market. The scope of the report far exceeds any feasible in-depth summary in this thesis, but quantitative data about PV production trends were used to support topics of this section and any pertinent subsequent findings. China and Taiwan produced 59% of the world's PV cells in 2010, with the U.S. falling behind Europe and Japan with only 5%. The EERE report shows annual world PV cell production increased from just less than 4 GW in 2007 to roughly 23.8 GW in 2010. Historically, U.S. PV production exports exceeded imports. That changed in 2005 when imports and exports were nearly even. From 2006 until present U.S. PV cell and module imports have exceeded export numbers. The market signals that influence PV adoption are highly correlated to retail cost of modules and ultimately the installed cost of a system on a home or ranch/farm. Therefore, consumer behavior (*i.e*. demand) is a reaction to the cell efficiency, which is a result of semiconductor material availability, which is a result of manufacturing cost effectiveness, which can be said, is a factor of environmental regulation, trade policy with foreign manufacturers, transportation costs, etc. etc. The point is that each barrier pushes and pulls on the others, creating a complex web of issues that cannot easily be discerned by the average PV consumer. The review of the 2010 Solar Technologies Market Report provided me with a multi-faceted take-home message. First, the economics of PV technology determines the extent of its adoption. Second, currently the moderately-efficient, moderately-expensive PV modules (e.g. c-Si) control the lion's share of market. Finally, the import of foreign manufactured PV modules have made them more affordable because to lax environmental regulations in countries like China. Domestic production does not compete on a cost-basis as a result of current China's loose environmental regulations regarding the disposal of harmful by-products, and economies-of-scale for semiconductor manufacturing (NREL 2010 & 2011, SVTC 2009).

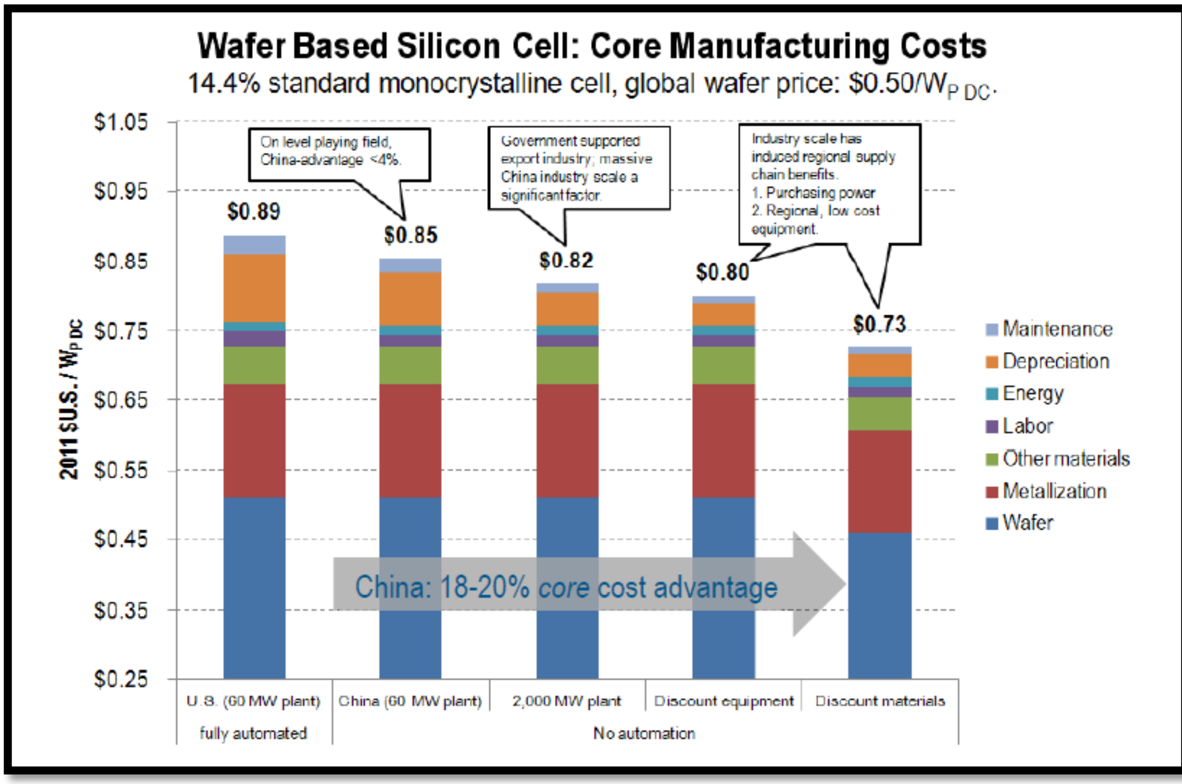


Figure 1: China's Comparative Advantage for Si Cells

(**Source:** NREL 2011)

Economics

Of the three barriers discussed in the thesis, the economics of implementing RE systems in the Residential sector proved to be the most daunting. Again, no one barrier is alone in explaining the "big picture" and all three feed into and off of each other. However, people seem to be most concerned with the up-front cost of RE and payback periods. Is there value in installing PV or small-wind at my home? Of chief concern is the *monetary value* associated with participating in behavior that can provide quantifiable data regarding the environmental value of RE, followed by the psychological value from knowing the benefits of RE. There have been extensive and intensive studies on the economics of implementing RE into the Residential sector by both the public and private sectors. This thesis utilizes three peer reviewed papers published by NREL on financing RE systems in the Residential sector to highlight the economic barrier.

NREL Report 1:

First, a report titled *Solar Photovoltaic Financing: Residential Sector Deployment* (Coughlin & Cory, 2009) discusses three emerging financing models for residential PV. They are the Third-Party Ownership, Property Tax-Assessment, and Monetizing the Value models. Also, discussed are three case studies of specific locations at Sacramento, California, Boulder, Colorado, and Newark, New Jersey on the significance of incentives and the need for financing to support PV systems. Coughlin and Cory (2009) state:

> Residential PV systems produce two commodities of value: 1) electricity and 2) the environmental attributes of that electricity. The production of these commodities can be financed directly by cash incentives provided by the state and local utility, federal and state tax credits, through the sales of renewable energy certificates (RECs), or indirectly by third parties who can more efficiently monetize these incentives for the benefit of the homeowner. While traditional models for financing residential systems are well-understood, there are a host of new and creative financial structures that have been developed with the goal of broadening the access to PV-generated electricity at the residential level. (p. 1)

The authors point out that on-site electricity generation offsets the cost that residents pay per month for utility provided energy at the retail rate. In states that have higher than average rates (e.g. CA, CT, HI, NH, VT) PV systems are more economically feasible and have a shorter pay-back period. In Nebraska the retail rate of electricity is below the 2012 national average of $0.1171 per kWh at $0.0911 per kWh for the Residential sector (EIA 2012). It stands to reason that because of the low rates in this state the return on investment (ROI) can be lengthy depending on several factors such as monthly consumption, site specific PV capacity factor, module efficiency, installed cost, etc. The other aspect of utility bill savings discussed by Coughlin and Cory (2009) is “net metering” (p. 5). Net metering is different from the savings generated behind-the-meter as previously mentioned in that any electricity generated by an RE system in excess of the amount consumed by the homeowner each month, spins the meter backward lowering the net number of kWh purchased from the utility. Essentially net metering acts as a credit from the utility that is applied to the homeowner at the end of the month or year. Net metering rates depend on the state’s regulation and utility policy. In Nebraska, the rates are set at the “avoided generation cost” (p. 5) of what it would take the utility to generate the electricity. For example, LES' net metering rate is $0.047 per KWh and NPPD's summer/winter rates are wind = $0.0493/$0.0403 and PV = $0.0913/$0.0507 per kWh, respectively (LES & NPPD 2012). The effect of the "avoided cost" rate is analyzed in further detail later in the **Discussion** section. Coughlin and Cory (2009) discuss the difference in net metering policy in their report by saying "The utility will either purchase any outstanding net metering credits at the end of the month or year (usually at a wholesale generation rate) or reset the amount to zero with no payment whatsoever for the homeowner" as a result, "This is not a beneficial outcome for the homeowner, it acts as a disincentive" (p. 5).

The report also examines other cash-back incentive programs designed to lower the upfront cost of RE systems. Included are state specific capacity based rebates expressed as dollar/watt terms, Renewable Energy Credits (RECs), which discussed under the heading, and tax-based incentives, such as the Investment Tax Credit (ITC) established under the federal Energy Policy Act of 2005.

Coughlin and Cory (2009) provide a valuable assessment of the financial breakdown for installing a residential PV system in the three case studies at their specific location sites. The authors used an $8.30/watt value which was based on the average of 5,885 installations from 2007 data provided by NREL. The 4kW systems outlined in the report were assumed to have a $33,000 dollar install cost prior to any rebates or incentives. The cost of each system was then calculated using each cost reducing factor previously discussed to show final results for the homeowner cost at each site. In each case the expected electricity production was calculated over a 12 month period over 20 years with an annual 1% degradation rate. **Table 1** illustrates the Net Present Value of electricity produced over a 20 year period with a 2007 average rate of $0.14/kWh and $0.09/kWh for Sacramento/Newark and Boulder, respectively. Other assumptions were an annual increase in retail electricity rates of 5% over the 20 years and a discount rate of 7%. For comparison purposes I used the Boulder, Colorado case because it is geographically nearby Nebraska and differences in irradiance values are minimal. Also, the average rate of $0.09/kWh is close to the current state average rate in Nebraska. It should be noted that neither LES nor NPPD currently offer the rebates for RE systems as outlined in the Boulder case. Therefore, the up-front cost to the homeowner is assumed to be higher in Nebraska, all other variables held constant. The significance of this analysis is to provide the reader with a graphical representation of the structural framework of cost breakdown in which to view RE systems in Nebraska. The following page displays the corresponding tables and figures used to explain the Boulder case and its legitimacy to this thesis work.

Table 1: Electricity Production and 20-Year Electricity Cost of 4 kW PV System

City	Annual average electricity production (kWh)	20-years of electricity production (kWh)	Cost per kWh over 20 years
Sacramento	5,597	101,918	$0.32
Boulder	5,834	106,233	$0.31
Newark	4,732	86,156	$0.38

(**Source:** Coughlin & Cory, 2009)

Table 2: Levelized Present Value of Electricity Generated and the Resulting Up-front Cost Offset

City	Present Value of electricity (20 years)	As a percentage of up-front cost
Sacramento	$8,301	25%
Boulder	$5,562	17%
Newark	$7,018	21%

(**Source:** Coughlin & Cory, 2009)

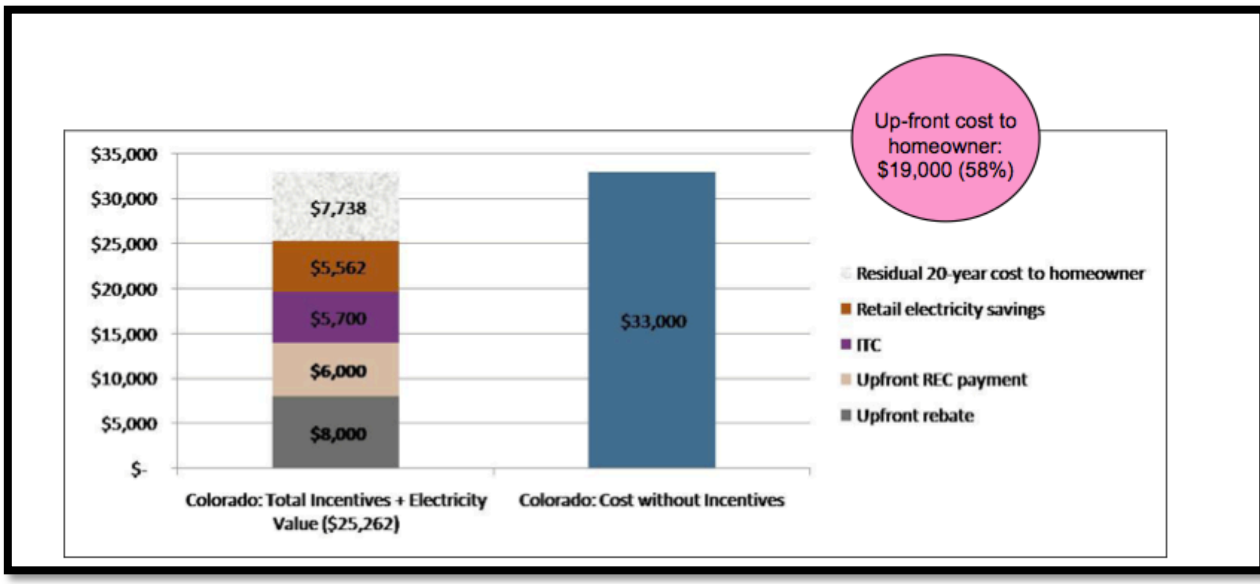


Figure 2: Total PV system cost to Boulder homeowner, including incentives

(**Source:** Coughlin & Cory, 2009)

Coughlin and Cory (2009) explored the emerging financing models available to residential PV systems. Those models are applicable to both PV and small-wind. The success of reducing the up-front cost barrier of RE is dependent on state regulations and utility policies where the consumer lives. The models discussed do not discriminate based upon technology, but are viewed from a PV perspective only because it is the scope in which the report was written. For theoretical analysis purposes the benefits of each model is assumed equal for both PV and small-wind in Nebraska and a parallel can be drawn on this conclusion. However, in depth analysis would likely show variations between the two technologies based on cost of equipment, labor, and O&M. The content is applicable to both RE systems discussed in the thesis and may help provide insight into the future of financing RE in Nebraska in the near-term.

The first model discussed is solar leasing. In a leasing program a customer enters into a contract in which they agree to make monthly payments over the life of the lease. The homeowner will experience savings from electricity offsets generated by the system, and may also take advantage of the state's net metering policy for further savings. The idea is that the monthly lease payment and the utility bill savings would be lower than the monthly cost of retail rates for electricity provided by the utility. At the end of the lease the homeowner may either choose to have the system removed, purchase the system, or extend the lease agreement.

Another model is third-party ownership or commonly called a power purchase agreement (PPA). According to this model the homeowner is free from any up-front costs of installing the system and future O&M because a third party provides all the capital for the system under the condition that the homeowner purchases all the electricity generated from the system over a period of time. Another benefit of this model is that third-party owner can take full advantage of federal tax incentives not available to the Residential sector. According to the contract the rate may increase by some pre-determined rate or remain fixed. The assumption under this model is that the agreed upon rate will be competitively lower than the utility price which is variable and ever rising. The three options available to the homeowner at the end of the contract are the same ones mentioned under the leasing model.

Finally, the property tax assessment model tackles the two barriers of 1) high up-front costs and 2) recouping the cost of a long-term investment (i.e. 20 years) when average homeowners may move several times in that period. Two pilot programs in Palm Desert, California and Boulder, Colorado provided the homeowner with loans to finance the system from the city's general fund or from issuing long-term bonds. The loan repayment is expressed as a special property tax owed to the city annually. If the homeowner moves then the new owner of that property assumes the tax. This way the original homeowner and the new owner only pay for and benefits from the system while they live there. The benefit comes in the form of reduced up-front cost to the homeowner installing the system via the loans, and savings on utility bills.

NREL Report 2:

The report titled *Future of Grid-Tied PV Business Models: What Will Happen When PV Penetration on the Distribution Grid is Significant?* (Graham, Katofsky, Frantzis, & Sawyer, 2008) discuss what they call 2nd Generation business models. Traditional business models for distributed PV are given as background, such as the ones mentioned in NREL Report 1, but this report explores business models beyond the near-term. Future models in which the likelihood of the utility stepping in to control and manage distributed PV is seen as significant, is the basis of the report. In economic terms the future models outlined by Graham, Katofsky, Frantzis, & Sawyer (2008) state, "The most significant finding in this study to date is that the full benefits of an extensive distributed PV resource are not likely to be realized without some degree of utility control and ownership" (p. 5). Meaning that currently the generating capacity of distributed RE systems is so minimal; utilities do not consider its potential influence on grid design issues. When RE market penetration is significant Graham, Katofsky, Frantzis, & Sawyer (2008) state, "A time will come—in some areas of the country much sooner than others—when the sheer number of installed distributed PV systems becomes a material and operational concern—or opportunity—for utilities. Policy and regulatory considerations will then be paramount" (p.5). Second Generation business models, as well as zero to first generation models are illustrated in **Figure 3** below.

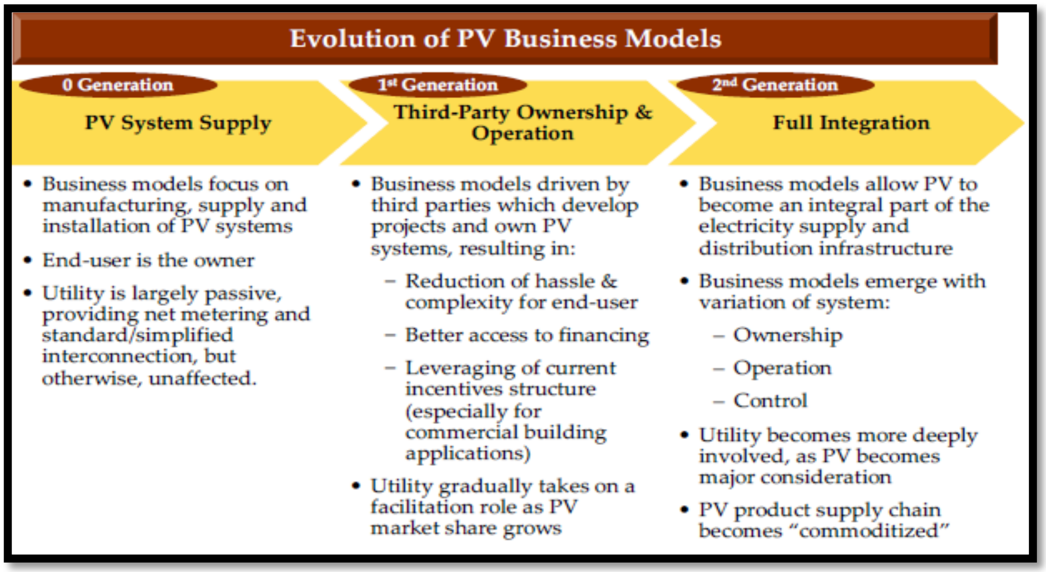


Figure 3: Evolution of PV Business Models (**Source:** Graham, Katofsky, Frantzis, & Sawyer, 2008)

NREL Report 3:

The final report featured in this section is titled *Residential, Commercial, and Utility-Scale Photovoltaic (PV) System Prices in the United States: Current Drivers and Cost-Reduction Opportunities* (Goodrich, James, & Woodhouse, 2012). In this report the authors compare the difference between the traditional ways of pricing a PV system using the "fair market value" (p. 2) to a pricing methodology referred to as "bottom-up" pricing (p. 3) developed by NREL. The main variance between the two methodologies was that the former, "Establishes the value of a PV system based on the capitalization of the expected cash flows from that asset" (p. 2) and the latter, "Characterizes the unsubsidized cash purchase price of PV systems, an objective measure that most closely approximates the *book value* of an asset" (p. 3) (Goodrich, James, & Woodhouse, 2012). The bottom-up pricing method is significant to this thesis and applicable to residential PV as well as small-wind because for accounting purposes a parallel can be drawn for the two technologies in how their valuation constructs are perceived by the Residential sector. The bottom-up approach is beneficial because, “The detailed results can be used to guide R&D efforts aimed at reducing PV system prices and to understand the potential benefits of proposed technological improvements” (p. 3) (Goodrich, James, & Woodhouse, 2012). For comparison purposes **Figure 4** below details the bottom-up pricing method for the 2010 benchmark price of a residential rooftop PV system as \$5.71 per peak watt (W_P) of direct current (DC). Note that in NREL Report 1 a 2007 national average cost of \$8.30 per watt of installed PV before any rebates or tax incentives was used for the analysis. The drop in cost over a five year period is significant.

It can be assumed that future leveled cost of energy (LCOE) will decline as technologies penetrate the market further, making RE more economically feasible. Also contributing to the decline in up-front costs of RE systems will be the new financing models available to homeowners in the future. Finally, although PV and small-wind are inherently different technologies, the issues discussed above for PV have merit regarding overcoming the economic barrier associated with small-wind adoption as well.

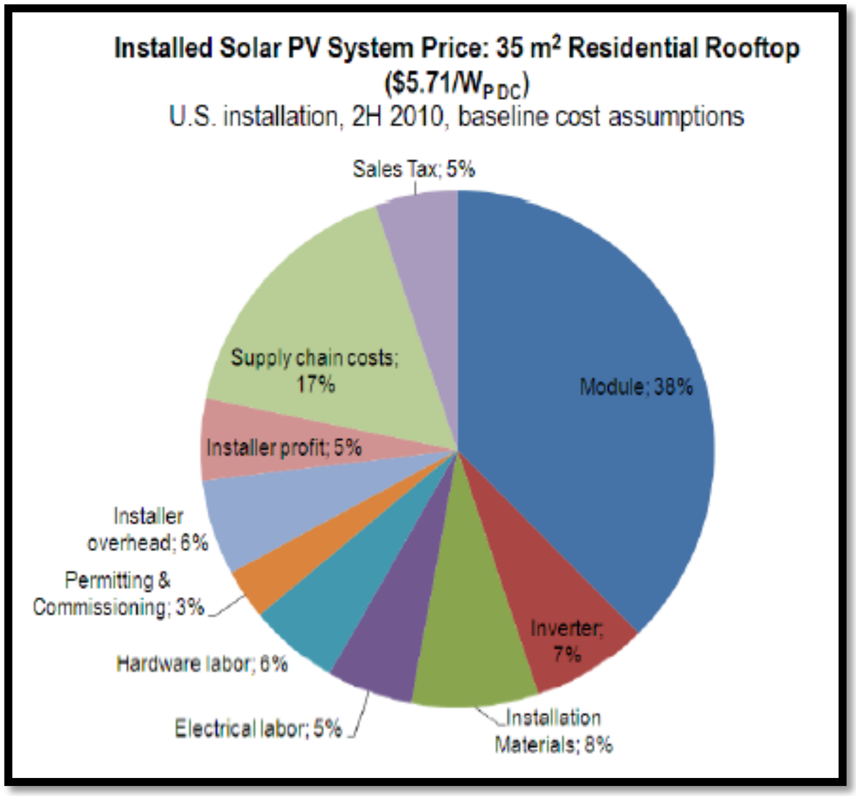


Figure 4: Benchmark 2010 residential PV system price: breakdown by element

(**Source:** Goodrich, James, & Woodhouse, 2012)

Socio-Cultural Issues

Social and cultural considerations were reviewed in an attempt to gain understanding of the softer issues creating roadblocks to RE adoption in Nebraska. Social-organizational factors and the resulting cultural norms and beliefs are not as quantifiable as the technological and economic issues discussed above. To a large extent government regulation and policy associated with the financial aspect of RE deployment falls under the socio-cultural heading, however those issues were discussed with adequate length in the previous section. Therefore, I will not make that topic redundant by going into it here. Mentioned earlier in the thesis was a fourth barrier I said would be touched on, but not debated over extensively. The next section covers the awareness and education aspect of identifying and overcoming barriers to RE deployment in the Residential sector.

Three case studies published by the DOE EERE in 2011 provided insight on the specific actions taken in the cities of Knoxville, Tennessee, Madison, Wisconsin, and Minneapolis-Saint Paul, Minnesota and the resulting lessons learned to break-down the barriers to adoption. All cities were designated by the DOE as Solar America Cities, a title bestowed upon 25 U.S. cities that were awarded funding to expand solar PV generating capacity through a comprehensive approach to urban solar energy use. The Solar America Cities and subsequent study was conducted from 2007 to 2010.

In Knoxville, the installed PV went from just under 30 kW to over 1.3 megawatts (MW). According to the study the top takeaways were, "Engaging and educating the public early and often is helpful to incorporating solar into municipal operations" and "Maintaining a positive relationship with local utilities and energy providers is essential" (p. 7) (DOE EERE 2011).

Madison PV capacity climbed from slightly under 200 kW installed for both residential and non-residential PV to over 800 kW installed capacity for both sectors. The report cited that, "Citizens need to be aware of the facts about solar and to understand its advantages and options through a network of freely available information" (p. 6) (DOE EERE 2011). The Madison study found the prospective solar owner agent (PSOA) to be the most influential factor in, “Reducing delays or ‘no go’ decisions from prospective system owners who are exasperated by barriers” (p. 6) (DOE EERE 2011).

Finally, Minneapolis-Saint Paul reported increasing a city-combined residential and non-residential 2007 installed capacity of about 140 kW to the 2010 value of nearly 1,100 kW of PV throughout the Twin-Cities. The study acknowledges that, “Building relationships across stakeholder groups is a slow process but critical to moving forward on any initiative.

Efforts to change policies or processes require the allocation of resources to engage stakeholders” (p. 7) and in order “To be effective and sustainable, market transformation requires action at state and local levels” (p. 7) (DOE EERE 2011).

The over-arching theme expressed by each case study is awareness and education needs should be pushed to the forefront of the movement. Progress can be made if people are aware of the possibilities provided by RE. Although, these case studies highlight an urban environment using PV, assumptions can be surmised about the potential for small-wind in rural settings. The dynamics of community and cultural based progression are not limited by geographic distances in our modern society. The examples displayed in those three cities could arguably be just as feasible with both RE systems in either a rural or urban environment in Nebraska assuming adequate socio-cultural changes take place over time.

Small-Wind

Many of the same barriers that exist for PV also exist for small-wind adoption. Therefore, I have not provided an in depth literature review for small-wind as I have for PV. Discussed below is the review of one peer reviewed technical report published by NREL in 2007. The authors contributing to the report identified seven different market segments. I have focused on two: small-scale remote or off-grid power, and the residential or on-grid power. These two segments are applicable to my research and provide valuable insight from experts in the industry. The report has been broken down into three sub-headings: technology, economics, and socio-cultural issues are examined.

Technology Issues

In the report Forsyth & Baring-Gould (2007) identify several technology based barriers to the adoption of distributed wind in several market segments. The most easily recognized obstacle was the concern for product reliability and performance. The authors point out that, "Performance is typically over-predicted (usually due to a poor understanding of the wind resource, the micrositing of the turbine system, and insufficient tower heights)" (p. 12) (Forsyth & Baring-Gould, 2007). Another problem is the lack of maintenance personnel to repair and service turbines in rural areas. Other issues discussed in the report include the lack of industry accepted testing, rating and performance standards, which undermines performance estimates for turbines and discrediting the industry. Finally, Forsyth & Baring-Gould (2007) cite, "The technical complexity and cost of interconnection of small wind systems to the electric distribution grid require further advancement, standardization, and testing" (p.12) creating yet more complications for residents who pursue small-wind.

Economic Issues

As with residential PV by far the most recognized barrier is the high costs associated with installing a small-wind turbine system. Forsyth & Baring-Gould insist, "Although markets exist in which incentive programs can be combined to give consumers 50% cost-sharing of their turbines, further cost decreases through volume manufacturing will be needed to allow appropriate payback periods for most American consumers" (p. 11). Also brought to light is the lack of consistent incentive policies. The authors state, "More systematic market incentives, such as 'feed in' tariffs, a national investment tax credit for distributed wind applications, and state-based rebates for all distributed applications would expand the technology adoption" (p. 11) (Forsyth & Baring-Gould, 2007) and increase the financial feasibility so the average citizen in Nebraska could see real payback over the life of the system.

Socio-cultural Issues

Past negative experiences associated with small-wind have created a belief that there is no benefit to utilizing a small wind system. There is a historically poor image associated with small-wind that is due to under-performance of older systems that were not sited correctly or not efficiently designed to capture the potential in low-wind regimes. Siting considerations and advances in modern designed turbines are extremely important, as Class 3 to 4 wind resources can make small-wind cost effective in locations with good policy and existing high electricity rates. Forsyth & Baring-Gould (2007) point out, “Outreach activities addressing previous market issues and some of the largest preconceived notions of modern small wind turbines are needed” (p.11).

Conclusion

Many of the barriers affecting residential PV apply to small-wind and vice versa. The technology, economic, and social barriers detailed in the past work by other industry experts exist in Nebraska. Of the three obstacles at play, the economic (i.e. financing) of RE systems for the Residential sector is the most difficult to overcome. Addressing the issue and utilizing some the emerging business models to reduce the high up-front costs of RE can help dissolve the negative perception associated with these types of systems. Each barrier is in some way affected by the others and also affects the others. Using a systematic problem solving approach is key to unlocking the potential of RE in the state. Placing each component under the microscope and examining its role in the problem allows for solutions to be easily mapped out and applied to the larger perspective. The components of the data collection portion of the thesis are outlined in the next section. A comprehensive look at the equipment utilized in the real world applications of a PV and small-wind system, and relevant literature are discussed in the Methods and Materials portion of this report.

Methods and Materials

Focusing on residential-scaled RE systems, I will explore how influences such as economics, social factors (i.e. policy, cultural values and norms) and technology affect the adoption of RE systems in Nebraska. This section discusses technical aspects of the equipment used in the data collection process and data analyzed from a survey conducted by Dr. Jerry Hudgins from the Electrical Engineering Department at the University of Nebraska – Lincoln in collaboration with NREL. The survey was used to investigate the Residential sector awareness and attitude toward wind and solar electricity generation in Nebraska.

Included are two different types of data, quantitative and qualitative. Data was used to determine electrical energy generation via small-wind and solar PV systems over a 12-month period. Data collection began on the wind turbines in February of 2011 and ended in February 2012. Data collected from the solar PV system began on February 27, 2011 and ended February 24, 2012.

Quantitative Data

Quantitative data was obtained from three Skystream 3.7 wind turbines, located at the NPPD Operations Center in Norfolk, NE. The turbines were mounted at 30, 45, and 60 feet heights above ground level (AGL). The turbines are connected to an electronic data logger which fed information to a web-based software program named *Skyview* that displayed and recorded wind speed in miles per hour (mph) and energy output as kilowatts per hour (kWh). Skyview recorded the data in real time (ten minute lag time for actual output) on a website maintained by NPPD (http://noc.nppd.greentouchscreen.com/). I used the average monthly output of each turbine over a one-year period beginning in February 2011.

Data for the solar PV system was obtained through a website maintained by Enphase Energy, a microinverter manufacturer, on a fourteen module array located in Lincoln, NE and installed by Dixon Power Systems. The array consists of Sanyo HIT Power N210 modules that are rated at 210 watts each. Enphase allows the homeowner to record behind-the-meter electrical production and display the output via a web-based software program named *Enlighten* for system performance and monitoring purposes. The data obtained from this location was displayed via the Enphase link provided by the installer. Customer approval was granted for the collection of the information. Confidence in the data accuracy is supported by the legitimacy of NPPD and Enphase Energy.

Qualitative

Qualitative data used in the report was obtained through a 2010 survey administered in a collective effort by Dr. Jerry Hudgins of UNL's Electrical Engineering Department and in collaboration with UNL's Biological Systems Engineering and Entrepreneurship areas as well as the NREL. Surveys were sent to 2,267 wind energy community stakeholders in Nebraska. Stakeholders included landowners, wind energy advocates, members of regulatory agencies, state, county and municipal policy makers, member of the energy sector (e.g. utility companies), federal agencies, members of the Agriculture sector, and environmental organizations. Questionnaire were mailed and made available online to the sample population. Response success was 9.8% with 223/2,267 responses to the questionnaire. The survey asked fourteen questions on a wide array of topics from local economic impacts and emissions reductions to human health/safety to noise and property values. The questionnaire was conducted to evaluate priorities of stakeholders in the wind energy community in Nebraska. Due to non-scientific goals the sample population was not anonymous random sampling, and not intended for statistical or scientific analysis.

Technology

Wind Turbine

A Skystream 3.7, manufactured by Southwest Windpower, was a likely choice for collecting data for several reasons. First, the turbine is recognized in the industry as a reliable and efficient product with outstanding performance, thereby providing data with low variance. Second, the system installed at the NPPD Norfolk Operations Center was already in place and output had been recorded since installation in 2010, providing reliable historic data. Last, the Skystream 3.7 turbine is a common choice for Nebraskans to install because of its cost, reputation and market share in the small wind turbine industry. **Table 3** below contains the product specifications for the Skystream 3.7. The analysis will be discussed in the ***Results*** section.

Table 3: Skystream 3.7 Wind Turbine

Skystream 3.7 Specifications	
AWEA Rated Annual Energy	3,420 kWh*
Rated Power	2.1 kW at 11 m/s
Nominal Power	2.4 kW at 13 m/s
Energy Monitoring	Skyview™ wireless communication & monitoring system
Weight	170 lb (77 kg)
Rotor Diameter	12 ft (3.72 m) Swept Area: 115.7 ft^2 (10.87 m^2)
Type	Downwind rotor with stall-regulation control
Direction of Rotation	Clockwise looking upwind
Blade Material	Fiberglass reinforced composite
Number of Blades	3
Rotor Speed	50-330 rpm
Tip Speed	213 ft/sec. (66 m/s)
Alternator	Slotless permanent magnet brushless
Yaw Control	Passive
Grid Feeding	Southwest Windpower inverter 120/240 VAC 50-60 Hz
Braking System	Electronic stall regulation with redundant relay switch control
Cut-in Wind Speed (power production starts)	6.7 mph (3.0 m/s)
User Control	Wireless 2-way interface remote system
Survival Wind Speed	140 mph (63 m/s)

(Source: Southwest Windpower, 2012**)**

Figure 4: *Skystream 3.7*

(Source: AWEA 2012**)**

Residents considering installing a small-wind system can use several online assessment tools and models to get a rough estimate of a system's output, performance, and cost. A few such tools/models include ReEDS, SAM, JEDI, FinanceRE, and the Bergey Excel spreadsheet Cash Flow Model (NREL & Bergey.com 2012). I employed the SAM and Bergey Cash Flow analysis-modeling tool to compare the real world cost per kWh from the NPPD Norfolk Operations Center. Designed by the National Renewable Energy Laboratory the System Advisor Model (SAM) was chosen for the user-friendly interface and parameter input simplicity. The SAM and Bergey Cash Flow spreadsheet analysis tool is one of the easiest to use for residents who want to perform a site assessment using this technique. Analysis of the model is discussed in more detail in the ***Results*** section of this paper.

Photovoltaic

The PV array featured in this report is composed of fourteen Sanyo HIT Power 210N Photovoltaic Module(s). The system had an output power rating of 2.94 kW. The modules are connected using one Enphase Microinverter M210 per module. The microinverter's design allows for direct connection between the PV module in the array and the microinverter, which is mounted on the underside of the module (Enphase Energy 2011). **Tables 4**, **5** below provide product specifications for the Sanyo PV module and the Enphase Microinverters, respectively.

Feasibility of residential PV systems is determined by several factors, one of the most important is the availability of the fuel source. The amount of solar radiation, represented as watts per meter squared (W/m^2) is one element that dictates the energy output from a module. PV manufacturers rate models according to two different standardized test conditions. The

PVUSA Test Conditions (PTC) rating, tests PV systems under 1,000 W/m^2 solar irradiance, at 20° C, with wind speeds of 1 meter per second (m/s) at 10 meters AGL. The Standard Test Conditions (STC) rating tests PV systems at 1,000 W/m^2 solar irradiance, at 25° C cell temperature, air mass = 1.5, and ASTM G-173-03 reference spectra. The PTC rating has more "real world" value and is usually lower than the STC, which is conducted under factory conditions. The PTC better reflects what PV systems may generate under actual solar and climatic conditions (Riordan & Hulstrom, 1990, Pure Point Energy 2010). Each resident considering installing a PV system should perform a site assessment to calculate the amount of solar radiation available to the system by calculating the sun's azimuth angle and altitude relative to the modules position on earth, in order to maximize performance based on the modules orientation and tilt relative to the sun. The performance of PV modules can also be affected by weather conditions, shading, cell efficiency, and electrical system losses.

Residents interested in performing a site assessment for a PV system can use online analysis models, similar to the ones for small-wind; they include models such as HOMER, IMBY, and SMARTS (NREL 2012). I employed the IMBY analysis tools to compare cost per kW of a simulated 4 kW array sited on the south-side of the Capital Building in Lincoln to the residential PV site in Lincoln. IMBY is similar to SAM in user-friendliness, but only assesses PV potential for a given site. The IMBY analysis is discussed in the ***Results*** section of this paper.

Table 4: Sanyo PV Module

Electrical Specifications	
Model	HIT Power 210N or HIP-210NKHA5
Rated Power (Pmax)[1]	210 W
Maximum Power Voltage (Vpm)	41.3 V
Maximum Power Current (Ipm)	5.09 A
Open Circuit Voltage (Voc)	50.9 V
Short Circuit Current (Isc)	5.57 A
Temperature Coefficient (Pmax)	-0.336%/ °C
Temperature Coefficient (Voc)	-0.142 V/ °C
Temperature Coefficient (Isc)	1.95 mA/ °C
NOCT	114.8°F (46°C)
CEC PTC Rating	194.8 W
Cell Efficiency	18.9%
Module Efficiency	16.7%
Watts per Ft.[2]	15.48 W
Maximum System Voltage	600 V
Series Fuse Rating	15 A
Warranted Tolerance (-/+)	-0% / +10%

(Source: Enphase Energy, 2012**)**

Table 5: Enphase Microinverter

Input Data (DC)	M210-84-208-S12	M210-84-240-S12
Recommended input power (STC)	240 W	240 W
Maximum input DC voltage	62V	62V
Peak power tracking voltage	31V - 50V	31V - 50V
Min./Max. start voltage	38V/62V	38V/62V
Max. DC short circuit current	12A	12A
Max. input current	10A	10A
Output Data (AC)		
Maximum output power	210W	210W
Nominal output current	1.00 A	.88 A
Nominal voltage/range	208V/183V-229V	240V/211V-264V
Extended voltage/range	208V/179V-232V	240V/206V-269V
Nominal frequency/range	60.0/59.3-60.5	60.0/59.3-60.5
Extended frequency range	60.0/59.2-60.6	60.0/59.2-60.6
Power Factor	>0.95	>0.95
Maximum units per branch	18	13
Efficiency		
Peak inverter efficiency	96.0%	96.0%
CEC weighted efficiency	95.5%	95.5%
Nominal MPP tracking	99.6%	99.6%

(**Source:** Enphase Energy, 2012)

Results

Norfolk and Lincoln Sites

The 12 month analysis of the three turbines in Norfolk and the PV array in Lincoln are displayed in **Table 6** below. The nameplate capacity for each respective system along with actual system outputs, capacity factors, cost per system and cost per kW is outlined in the table.

PV

The capacity factor for the PV array was calculated using the following set of equations:

Total electricity produced over 362 days = **4,290** kWh (Enphase Energy 2012)

Total number of day from 2-27-2011 until 2-23-2012 = **362** days

Hours in one day = **24**

Nameplate capacity of array = 14 x 210 watt modules = **2.94** kW

(4,290 kWh) / [(362 day) x (24 hr. /day) x (2.94 kW) x] = (0.1679) x (100) = 16%

Refer to **Appendix A** for actual output reading of PV array.
Refer to **Appendix B** for statewide solar radiation potential produced by NREL.

Small-Wind

The capacity factor for the turbines was calculated using the following set of equations:

Total electricity produced over one year = **2,831** kWh (NPPD 2012)

Annual nameplate capacity = 2.1 kW at 11 m/s x (8760 hrs. per year) x 3 turbines = **55,188** kWh

1. **(2,831 kWh) / (55,188 kWh) = (0.00512) x (100) = 5%**

Actual output value came from the web-based logging tool and nameplate capacity was calculated using the nameplate capacity provided by Southwest Windpower for a Skystream 3.7 turbine at 11 m/s or approximately 24.6 mph (Southwest Windpower 2012). A low capacity factor for this system is likely due to short tower setting averaged at 45 AGL for all three.

Refer to **Appendix C** for results of the small wind system.
Refer to **Appendix D** for a statewide wind potential map produced by NREL.

Table 6: Comparison of PV and Small-Wind systems

System	Components	Nameplate Capacity (annual)	Actual output	Capacity Factor	Total Cost	Cost/kW
PV	14 modules	25,754 kWh	4,290 kWh	16%	$19,000	$6,462
Wind	3 turbines	55,188 kWh	2,831 kWh	5%	$57,406	$7,973

(**Source:** Jerrod Bley 2012)

Online Assessment Tools

Running the free online tools and models produced results that were fairly accurate with that observed in the real-world RE applications in Norfolk and Lincoln. Output values from the models were lower than real-world numbers on all occasions. Values from the online tools/models were the result of input parameters, some entered by myself and some that were built into the models. Manipulating output values is possible with all the simulation tools, but knowledge of accurate input parameters (e.g. loan amount, interest rates, incentives, local utility rates, capacity factors, etc.) is essential for a useful assessment. The more informed the user is regarding all input parameters, the more realistic and beneficial the results will be. The result of each model-scenario is displayed in **Table 7** at the end of the section.

The IMBY model used to assess the PV application on the south side of the Nebraska Capital Building yielded interesting results. The IMBY standard 4 kW, residential rooftop PV system produced 5,832 kWh over a 12-month period. The value of the electricity produced was calculated to be $524.88 in USD$_{2005}$ based on a $0.09/kWh electricity rate. The initial cost of the system was $22,840 which is equal to $5,710/kW$_{DC}$. The after incentive price of the system was $22,800. This was the cost without any rebates or incentives calculated in. The payback period was calculated to be 41.41 years.

Small-wind assessment came from the SAM model and the Bergey Cash Flow (Excel spreadsheet). Results from SAM were limited to the final installed cost of the system. No estimated performance output was calculated form the model. The system was composed of one Skystream 3.7 turbine with a nameplate capacity of 2.1 kW mounted at 15 meters AGL at the NPPD Norfolk Operations Center address. Only the NPPD retail electricity rate was used for an input parameter. All other inputs were built into the model. The price for one turbine was $8,640 with an installation cost of $2,000. An 8% contingency fee (contingency applies to the total cost of turbine, installation, and BOS) equal to $851.20. Also calculated was an indirect cost of $574.56 from a 5% sales tax, for a total cost of $12,065.76 or $5,027.40/kW. This was the cost without any rebates or incentives calculated in.

Results from the Bergey Cash Flow model were derived from input values that reflect the actual post-install cost of the NPPD three turbine system and actual output values from the system over a 12 month period. The up-front cost for all three turbines was $57,460 USD_{2010} (NPPD 2010) or $7,973/kW. A no-financing option on the spreadsheet was used, implying a cash purchase of the equipment. The spreadsheet uses a $0.005/kWh annual O&M cost over a 30-year period. Utility retail cost entered was $0.09/kWh which is a rounded value provided by the EIA for average retail cost of electricity in Nebraska in 2012. An electricity cost inflation rate of 5% was entered, based on the value used by Coughlin & Cory (2009). The average monthly savings on electricity in year 1 = $77, year 10 = $125, year 20 = $204, and year 30 = $333. The analysis of cash flow showed a 0.2% internal rate of return (IRR) and a positive net payback amount (e.g. the value of electricity generated) of $1,775 coming from year 30. Years 1 to 29 the value of electricity generated was still being used to pay off the system's initial cost.

Another cash flow analysis was performed using a total system cost of $12,650 with an annual nameplate capacity of 3,420 kWh (estimated annual energy output from Southwest Windpower spec sheet). Cost was taken from the SAM model for a Skystream 3.7 and the output was provided by the Southwest Windpower for AWEA annual rating on the same turbine. All other factors held constant. The IRR was 2.8% and a positive net payback of $7,662 beginning in year 22. The average monthly savings on electricity in year 1 = $26, year 10 = $42, year 20 = $68, and year 30 = $111.

Table 7: Comparison of free online assessment tools/models for calculating RE system costs

System	Online Model/Tool	Nameplate Capacity	Total Cost	Cost/kW	Payback Period
PV	IMBY	4 kW	$22,800	$5,710	41
Wind	SAM	2.4 kW	$12,065.76	$5,027.40	NA
Wind	Bergey Cash Flow Analysis	7.2 kW	$57,460	$7,973	29
Wind	Bergey Cash Flow Analysis	2.4 kW	$12,065.76	$5,027.40	22

(**Source**: Jerrod Bley 2012)

Stakeholder Survey

Results from the survey are provided in **Table 8** below. Questions 1, 2, 3, 5, & 6 are provided below for reference in Table 8. Questions 4 & 9 are provided further below as a separate analysis is required for these questions because of the complexity and volume of answering options. The results for questions 4 & 9 can be found in **Figures 5, 6**. The significance of the results is examined in the ***Discussion*** section.

Questions:

1) "For me to invest in small-scale wind energy, I would expect the payback time, allowing me to recapture my investment and show a profit, to be…"
   a) 1 – 5 years
   b) 5 – 10 years
   c) 1 - 15 years
   d) 15 – 20 years
   e) 20 – 25 years

2) "Given the requirements you have for an acceptable payback time, how much would you be willing and able to invest in small-scale wind energy for use in your business and/or home at this time:"
   a) Nothing
   b) $1,000 - $10,000
   c) $10,001 - $50,00
   d) $50,001 - $100, 000
   e) $100,001 - $500,000
   f) More than $500,00

3) "When you consider an investment into a new technology like small-scale wind energy, what criteria do you take into consideration when measuring return on your investment? Assign a percentage to each criterion so that your total equals 100%"
   a) A reduction in the cost of doing business or operating my home
   b) An increase in alternative sources of revenue for my business
   c) Potential for early adoption advantages over my competitors
   d) A contribution to our national policy of energy independence
   e) Environmental concerns

5) "If you were to consider an investment in small-scale wind energy, which of the following best describes your preference?"
   a) Do it myself
   b) Invest with neighbors
   c) Invest as part of my local community

6) "Regarding the possible availability of tax incentives, grant funds, and low-interest loan funds to support your investment in small-scale wind energy, which best describes your current understanding:"
   a) I am completely unfamiliar with anything about small-scale wind energy use.
   b) I have heard a few things about small-scale wind energy, but I am unaware that any funding for individual investment is available to someone like me.
   c) I have heard that funds might be available, but I do not know anything about either small-scale wind energy of the potential for funding investment in it.
   d) I have heard that funds are available, but I do not know how to take advantage of any that might be available.
   e) Even if funding would be available, I would not be interested in obtaining it.

Table 8: Small-scale wind energy survey results

Question #	**Response % or average**	**Answer option**	**Comment**
1	53.0	B	5 - 10 years
2	58.1	B	$1,000 - $10,000
3	41.68	B	Reduction in cost of business or home
5	65.9	A	Do it myself
6	42.1	B	Unaware that funding is available to individual like myself

(**Source:** Jerrod Bley 2012)

4) “When computing your return on investments, to what extent would you consider cost and benefit data provided by each of the following to reliable?”

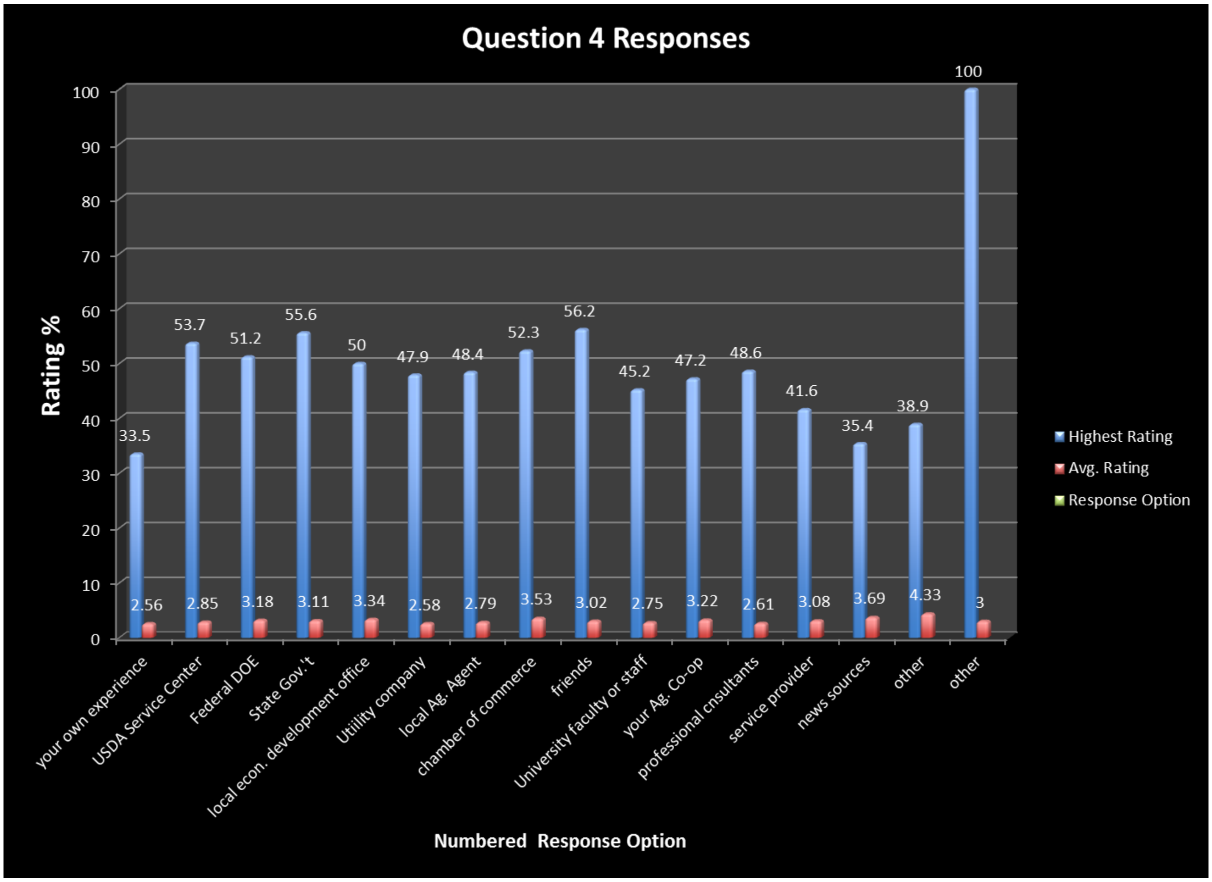


Figure 5: Question #4 Results

(**Source:** Jerrod Bley 2012)

9) “To what extent do you see each of the following as major obstacles to your willingness to invest in small-scale wind energy in the near future?”

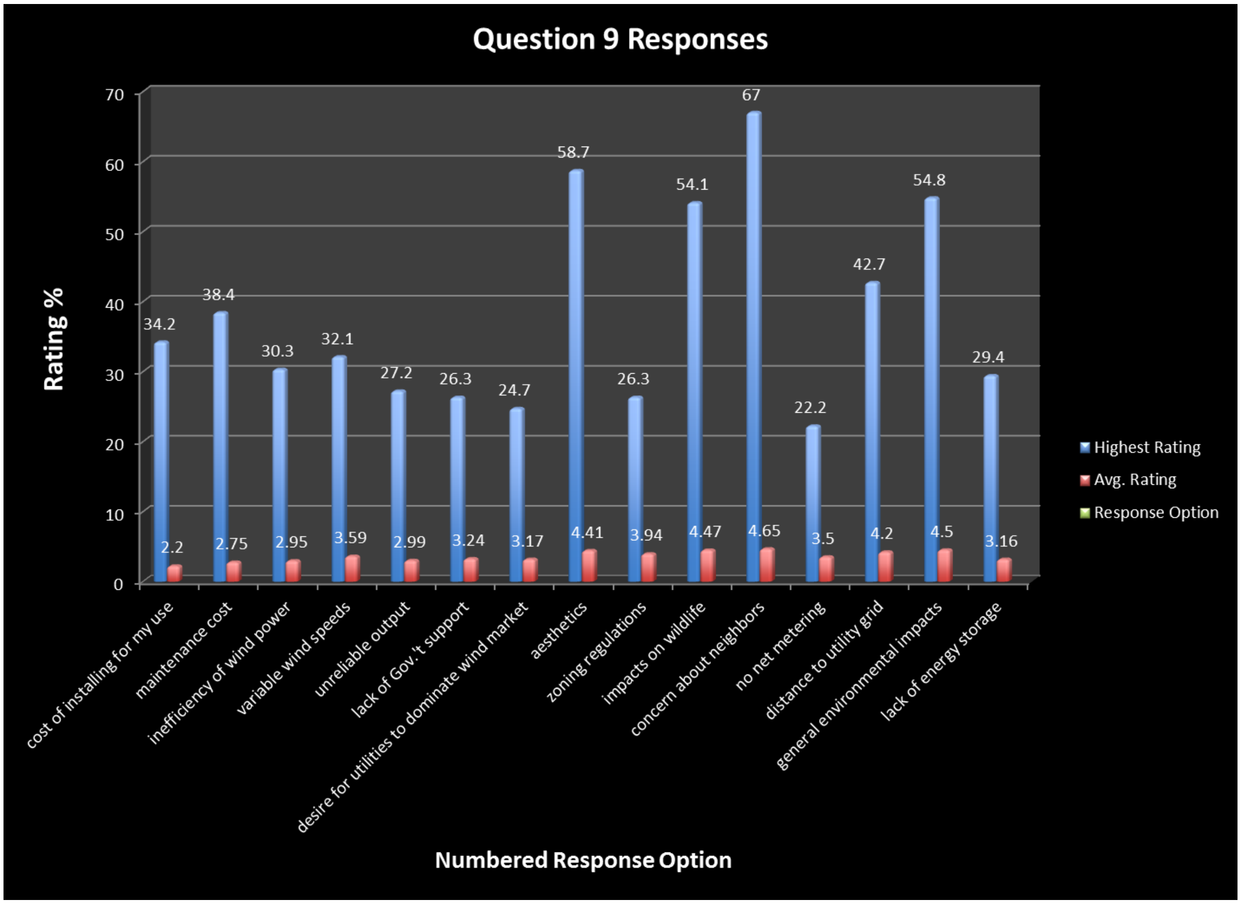


Figure 6: Question #9 Results

(**Source:** Jerrod Bley 2012)

Discussion

Real-world vs. Simulation: cost-benefit-analysis

A comparison of the real-world applications in Norfolk and Lincoln and the simulated online assessment yielded very different results. The simulations provide rough number calculation for comparison purposes.

Per kilowatt values from the IMBY model reflect 2010 benchmark costs of residential PV ($5,710/kW) according to Goodrich, James, & Woodhouse (2012). However, the actual cost of a smaller capacity system installed in Lincoln experienced a cost of $6,462/kW. The difference in cost is $752 which is not a very significant variance relative to the large up-front costs residents can expect to pay. One explanation for the difference seen in the two scenarios is the lack of consistency in the input parameters. I was only granted limited data on the actual cost of the real-world PV system and only had access to the cost before any rebates or tax incentives were utilized, if at all. It can be assumed that if incentives were used, the total up-front cost of the array may have been closer to the value calculated during the IMBY simulation.

Results from the SAM analysis tools yielded even larger differences than the PV scenario, when compared to the real-world system in Norfolk. NPPD reported a per kilowatt cost of $7,973 for a 7.2 kW system. That compares to $5,027.40 calculated from the SAM model. A difference of $2,945.6/kW installed small-wind. This is a significant difference between actual and simulated, and almost four times the difference observed in the PV scenario. Accounting for this much larger difference, again, is dependent upon the input parameters used in the SAM model. My experience with this online tool was limited. A lack of knowledge and experience can affect the results of a simulation because pertinent financial parameters are not entered. NPPD's current electricity retail rates are gathered by SAM via an online connection. This was the only input I directly administered. Potential RE owners should be well informed about the system being considered and all technical, financial, and tax-related issues should be known prior to running the model for budgeting purposes. If a potential RE owner is attempting to get a ball-park number for installing a system the SAM model will work, however the full potential of the program is not being utilized. For professional installers the SAM model is a more useful tool.

The Bergey Cash Flow analysis tool was used to illustrate the variations possible in payback periods, as a function of input parameters. The two scenarios differed in total cost of the system and the output capacity. The first simulation used actual values from the NPPD application (e.g. nameplate capacity & installed cost) provided by NPPD. The second simulation used values provided by the SAM model, which can be assumed reflect national averages for input parameters, and in this scenario specific NPPD electricity prices that I entered into SAM. The idea was to compare the payback period of a real-world system to that of one simulated using SAM. The results show a payback period of 29 years under the NPPD application and only 22 years under SAM simulation. There are many factors that affect the output values calculated using this analysis, however comparing the two scenarios gives the reader an idea of the number of years it may take to see payback from a small-wind system. It is possible to manipulate the analysis to see shorter payback periods, for example, one major limit to this analysis is that only the up-front cost of each system was analyzed. Rebates and tax incentives were not entered, nor were any other financing options. If cost reduction was reflected in the cash flow analysis the payback period would have been reduced. The benefit of this analysis tool is the ease to which residents can access it and use it for system assessments. Providing accurate input parameters that reflect actual financing options to homeowners will yield useful results.

With payback periods so lengthy, the immediate benefits of RE systems are hardly seen. As seen in the scenarios the time to see profits from a system can take decades even for a small system. The economic issue displays the most hurdles to overcome when compared to other barriers. It is also the most complex. Findings way to lower the cost of RE systems is paramount to the future of their deployment. Emerging financing models that were reviewed earlier can provide a promising future for RE in Nebraska. Residents will feel more comfortable investing in a project if the payback period can be lowered to an equally risky investment found in other parts of the market. If the economic benefits are not realized and made aware to residents, the success of overcoming other barriers will be severely hindered. If RE makes sense financially it will open the door to meeting with victory in the technology and socio-cultural battlefields. Furthermore, the state and utilities can catalyze the adoption of RE through regulation and policy change.

The two relevant incentives currently utilized in this state are the net metering policy (Busche, 2010) and the Federal personal tax credit for RE systems. Net metering rates are determined by the avoided cost of generating electricity for the grid. Eligible RE systems participating in this type of incentive see roughly a 50-60% of retail rate buyback price from the utility. Although, this policy is beneficial it could be considered a very "good" policy with modifications. First, the existing net metering law established under LB 436 (DSIRE 2012) is only applicable to RE systems 25 kW or smaller. Granted most residential PV systems are below this margin, but small-wind systems can be as large as 100 kW (AWEA 2007) providing financing challenges to higher capacity systems typically found on ranches and farms. Another flaw in the net metering law is the low rate of the avoided cost. It's understandable that utility companies feel distributed generation takes advantage of pre-existing infrastructure to deliver excess electricity back to the grid for a fee. However, the avoided cost rate is not calculated including the cost of externalities to the environment. If the value of reducing carbon emissions from RE was equated and included in the avoided cost, surely the rate of a kWh of clean energy would be worth more than the existing net metering rate. Finally, Nebraska's net metering laws do not allow for carry-over from one month to the next. At the end of each billing cycle the credit to the system owner is zeroed-out and the next billing cycle starts fresh. For small-wind and PV this creates a dilemma. Wind potential is greatest in the winter and PV potential is best in the summer. For example, if a small-wind system owner generates more electricity than s/he uses in a month savings will be seen behind the meter in avoided retail cost but also as a credit for each kWh produced that month at the net metering rate. However, the credit is not carried forward the next month if credits remain. Zeroing out each month means lost savings for the RE owner. If Nebraska allowed net metering credits to rollover each month and make an annual assessment that is then applied toward the account, the benefits and savings would be more recognizable to the owner. **Tables 9, 10** below illustrate the current and future trend of cost/kW for coal-fired power plants and solar energy, respectively. Comparison shows price differences are minimal, but the cost of coal-generated electricity is more expensive on the long-term.

Table 9: Cost and Performance Projection for a Pulverized Coal-Fired Power Plant (544 MW) With Carbon Capture and Sequestration.

Year	Capital Cost ($/kW)	Variable O&M ($/MWh)	Fixed O&M ($/kW-yr)	Heat Rate (Btu/kWh)	Construction Schedule (Months)	POR (%)	FOR (%)	Min Load (%)	Spin Ramp Rate (%/min)
2008	6890	–	–	–	–	–	–	–	–
2010	–	–	–	–	–	–	–	–	2.00
2015	–	–	–	–	–	–	–	–	2.00
2020	6560	6.02	35.2	12,600	66	10	6	40	2.00
2025	5640	6.02	35.2	12,100	66	10	6	40	2.00
2030	5640	6.02	35.2	12,100	66	10	6	40	2.00
2035	5640	6.02	35.2	12,100	66	10	6	40	2.00
2040	5640	6.02	35.2	12,100	66	10	6	40	2.00
2045	5640	6.02	35.2	12,100	66	10	6	40	2.00
2050	5640	6.02	35.2	12,100	66	10	6	40	2.00

Table 11. Emission Rates for a Pulverized Coal-Fired Power Plant with Carbon Capture and Sequestration

SO_2 (Lb/mmbtu)	NO_x (Lb/mmbtu)	PM10 (Lb/mmbtu)	Hg (% removal)	CO_2 (Lb/mmbtu)
0.055	0.05	0.011	90	32

(**Source:** NREL Cost Report 2012)

Table 10: Cost and Performance Projection for Solar Photovoltaic

Year	Capital Cost ($/kW)	Variable O&M ($/MWh)	Fixed O&M ($/kW-yr)	Construction Schedule (Months)	POR (%)	FOR (%)
Residential PV with a 4 kW (DC) install size						
2008	7690	–	–	–	–	–
2010	5950	0	50	2.0	2.0	0.0
2015	4340	0	48	1.9	2.0	0.0
2020	3750	0	45	1.8	2.0	0.0
2025	3460	0	43	1.7	2.0	0.0
2030	3290	0	41	1.6	2.0	0.0
2035	3190	0	39	1.5	2.0	0.0
2040	3090	0	37	1.5	2.0	0.0
2045	3010	0	35	1.4	2.0	0.0
2050	2930	0	33	1.3	2.0	0.0

(**Source:** NREL Cost Repot 2012)

The federal renewable energy tax credit for residents was established under the Energy Policy Act of 2005 and was modified in 2008 and 2009 (DSIRE 2012). The amount of credit available for qualifying systems depends on the date of installation. Any eligible PV or small-wind system installed after 12-31-2008 has no limit on the maximum credit for 30% of qualified installation costs. The federal renewable energy tax credit provides the most cost reducing incentive option for residents in Nebraska currently. Low-interest loans do provide some relief to the up-front cost of RE systems and can make a project see quicker payback if output capacity is properly matched to consumption, and the value of generated electricity recaptures the initial costs of installation over the period of time being assessed.

Small-wind Survey

As seen in the **Results** section the findings from the survey suggest Nebraskans have about $1,000 to $10,000 they are willing and able to invest in a RE system. The survey also suggests that people expect a 5 to 10 year payback period on their investment and they mainly want to see a reduction in the cost of business or operating a home. Results from questions 5 and 6 state the majority of residents would take on an installation project by themselves, and are unaware that funding is available to individuals like themselves, respectively. A simple analysis of the results illustrate that all three barriers discussed throughout this thesis are present in this sample. Residents do not have the adequate capital for installing a system, nor is the expected payback period feasible under existing conditions. Residents are not aware of available funding opportunities for RE systems and many would rather try to install a system themselves before engaging in a community based-approach or partnership of some kind. Questions 4 and 9 were more difficult to analyze given the volume of answer options. According to the results residents trust information provided by friends, the state government, and the USDA office as the top three picks in that order. The results point out people trust those closest to them the most on an issue many “friends” may be much uninformed about. Such evidence correlates to the socio-cultural barriers examined in the Solar America Cities reports from Knoxville, Madison, and the Minneapolis-Saint Paul (DOE EERE 2011). The one “other” option that is at 100% is an outlier and is not relevant to the analysis of this question because only one person responded to that option. Question 9 showed respondents considered what their neighbors thought about RE on their property, aesthetics, and general environmental impacts to be the top three greatest concerns in that order. Findings from question 9 suggest that people are concerned about environmental issues related to RE, but of more concern is the social implications of installing a RE system on their property. Overcoming the social norms and belief that our neighbors will be offended by something “different” on our property is imperative. Culturally affected roadblocks could be the quickest obstacles to conquer. Education and awareness efforts to inform people about the benefits of clean, renewable energy sources could turn the tide of RE deployment. Interactive and socially engaging programs will clear the way for change in local and state level governments. When residents realize the potential value of RE on an economic and ecological basis acceptance will increase. The drivers to RE deployment will emerge as solutions to the existing barriers. (Walker & Cass, 2007)

Conclusion

The importance of developing RE system adoption in the Residential Sector cannot be understated. Worldwide, energy consumption by this sector accounts for 40% of energy used (Mundaca, Worrell, & McNeil, 2010). Expanding the implementation of small-scale RE systems in residential homes is highly significant to the sustainability of the ecosystem and to a smaller degree, the state’s economy. Reducing our dependence of fossil fuel based electricity generation and increasing our renewable energy portfolio needs to be part of the dialogue between citizens and policy makers. Change will only come from the voiced concern of those those who will stand up. It is the responsibility of each citizen who envisions a clean-energy future to become informed, and involved in the issue. Governments at all levels should be held accountable, and need to consider policy change, in the form of carbon credits or taxing pollution, to correct for the negative externalities associated with the generation of electricity via fossil fuels. Positive changes could potentially spur RE industry in the Residential sector, and "good" policy coupled with consistent regulations could make it increasingly attractive for new and existing homes to install RE systems. Evolving technological efficiencies and designing systems on a sustainable time frame lower manufacturing costs and reduce GHG emissions. Overcoming socio-cultural barriers through outreach, education, and awareness of the ways flawed policy hampers adoption will have major consequences in the cultural environment. Government incentives, such as tax credits, low-interest loans, property tax assessment models and utility rebate programs, could make it more cost effective and feasible for homeowners looking to reduce the high up-front costs of RE.

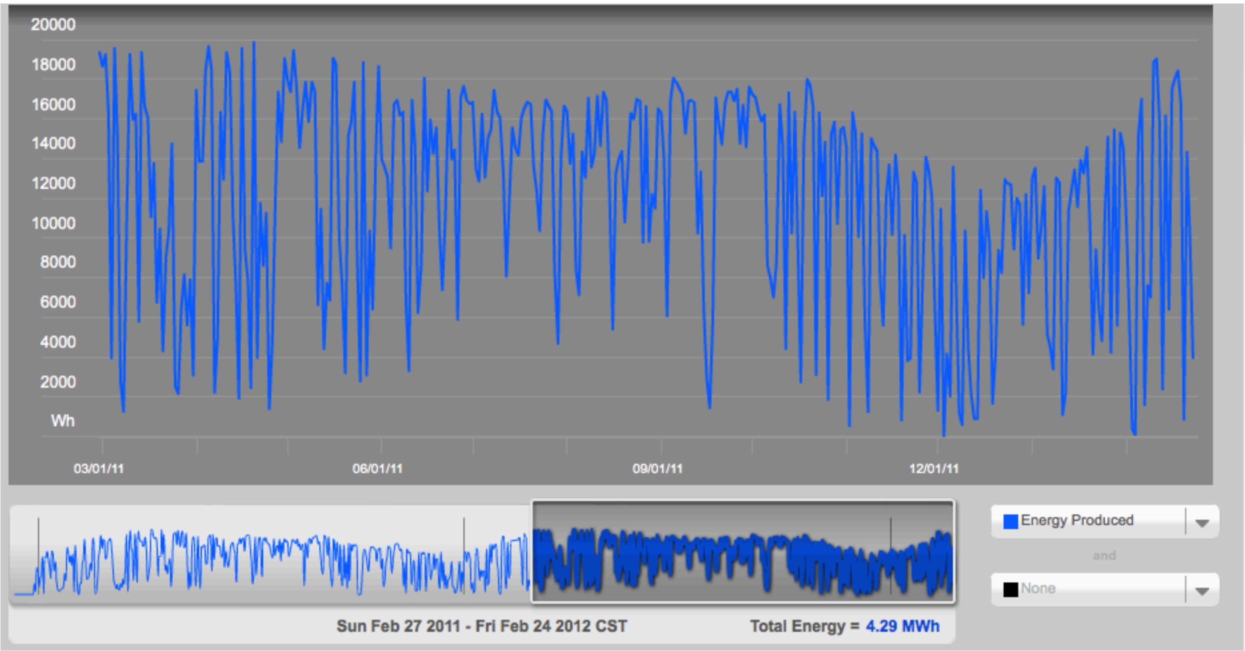
As is stands today, RE does not make financial sense to the homeowner, famer, or rancher. Retail utility rates are by far less expensive and more reliable for the end user; this is fact. However, when examining the issue through the window of environmental concern, I take the stance that we can't afford not to invest in a clean energy future. It will not be an easy transition, and it won't be a cheap-fix. Adoption will be a multi-generational effort, even if government regulation and policy change happens over-night. The cultural shift will take time and effort to fold into the fabric of society. Currently, distributed RE will not supply all the electricity needs of our society, but it can help. Each wind turbine that is erected; each PV module that is installed reduces carbon emissions and contributes to a healthier future. RE is not the fix-all but a part of the answer.

The continuation of the earth's biodiversity relies on the fundamental changes *we*, as a society, must make in the way we generate and consume electricity. In our search for the non-renewable fuels used to generate electricity, humans impinge on habitats and jeopardize the integrity of earth's plant and animal species. It is time to find an alternative to fossil fuels that allows us to produce clean, renewable energy while reducing our impact on the environment. You must ask yourself: "Are you part of the problem or part of the solution?"

Appendices

Appendix A:

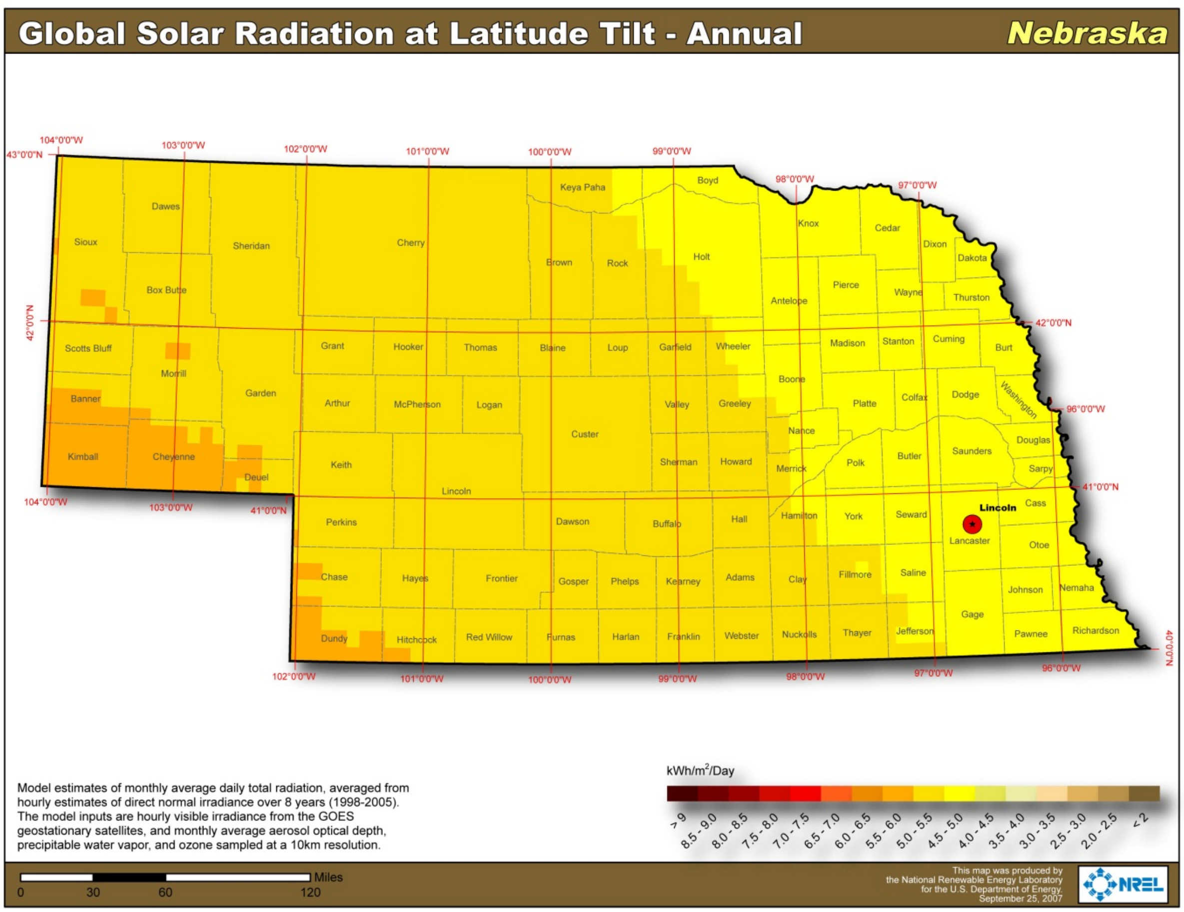
Reading from annual output of PV array located in Lincoln, NE



(**Source:** Enphase Energy 2012)

Appendix B:

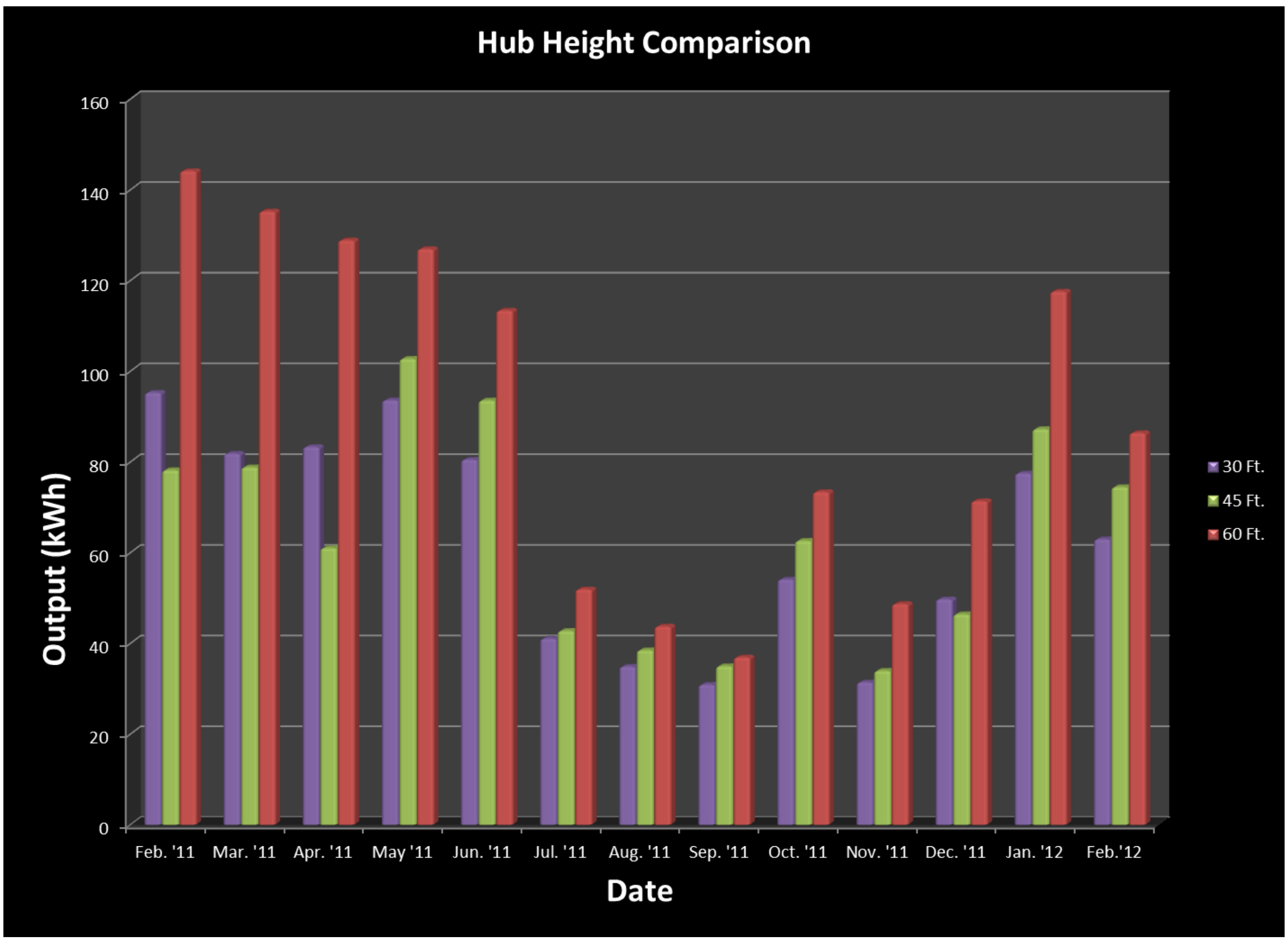
Solar potential map for state of Nebraska



(**Source**: NREL 2012)

Appendix C:

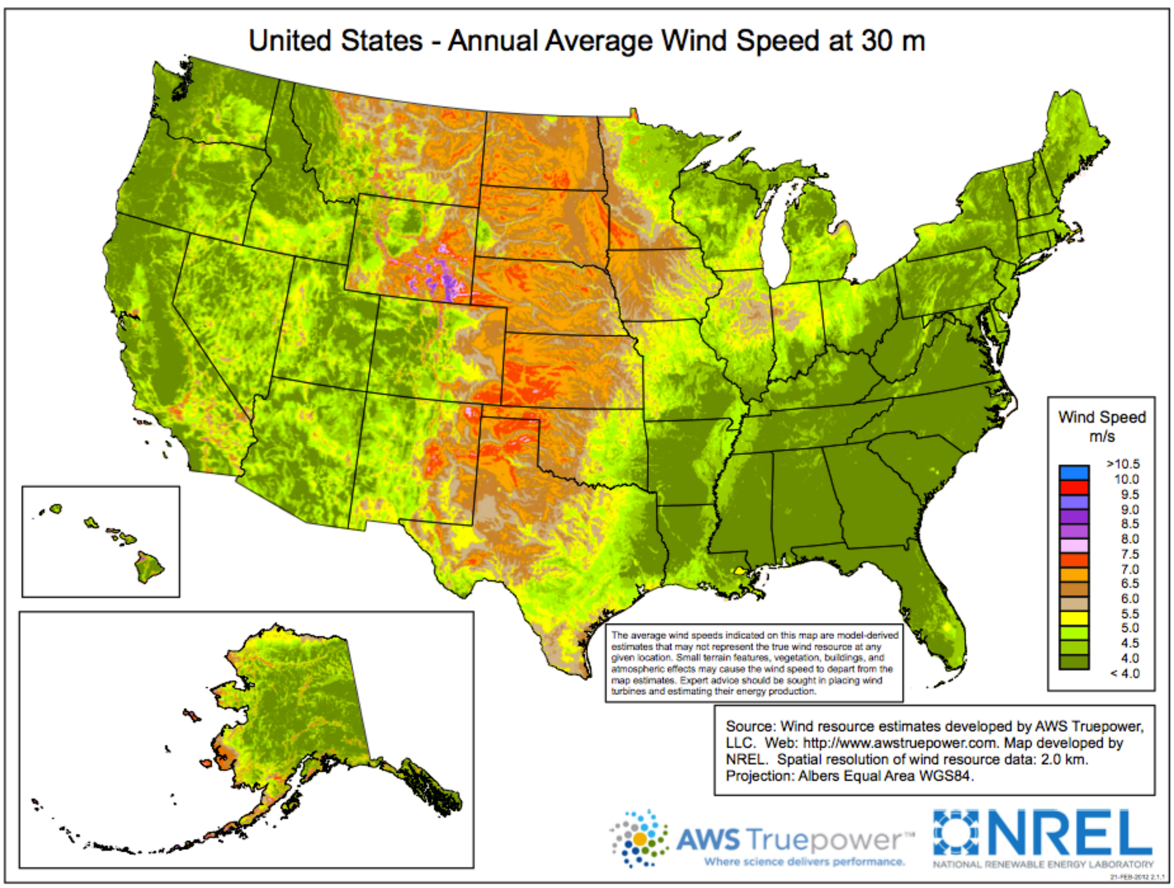
Annual output of all three Skystream 3.7 wind turbines located at Norfolk, Nebraska



(**Source:** Jerrod Bley 2012)

Appendix D:

Wind speed potential at 30 meters for state of Nebraska



(**Source:** NREL 2012)

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